SOILS AND FOUNDATION
REPORT NO. 03-08

PROJECT PRA-FOOT 8G14
LANDSLIDE REPAIR

FOOTHILLS PARKWAY
GREAT SMOKY MOUNTAINS NATIONAL PARK
BLOUNT COUNTY, TENNESSEE

PMIS # 119510

U.S. Department of Transportation
Federal Highway Administration
Eastern Federal Lands Highway Division
21400 Ridgetop Circle
Sterling, VA 20166

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Note: ***Design changes made subsequent to distribution of this report and prior to project advertisement will be documented in a memo inserted after the title page.***

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INTRODUCTION

GENERAL

This report summarizes the results of our subsurface explorations, laboratory testing, and design analyses and presents recommendations for repair of the failed slope for Project PRA-FOOT 8G14. The project is located along the Foothills Parkway in Blount County, Tennessee. The general site location is shown on Figure 1 in Appendix A.

PROJECT DESCRIPTION

The subject slide is located along an approximate 200 feet long section of the Foothills Parkway and is located in an area that is approximately 1.2 miles south of U.S. Route 321. Initial slope movement presented itself in the form of an approximate 1.0 to 2.0 feet wide crack that was observed by Eastern Federal Lands (EFL) Construction personnel on March 20, 2005. Following observation of the crack within the slope, the National Park Service (NPS) closed the northbound and southbound travel lanes within the slide limits. Traffic was detoured through the adjacent parking area after removal of debris from the roadway, placement of jersey barriers and placement of a temporary asphalt concrete pavement to connect the south end of the parking area with the Parkway.

EFL and NPS personnel conducted a field investigation on April 19, 2005 and made the following observations:

1. The width of the crack had increased to a maximum of 10.0 feet wide and that material within the crack limits had slipped consistent with rock bluff failures within the Great Smoky Mountain Region.

2. A scarp line had developed where rock blocks and slope material had rotated forward away from the hillside and had moved downward.

3. Broken rock and surficial debris (topsoil, soil, trees, etc.) had accumulated along the ditch line, parallel to the edge of pavement.

4. The scarp–which defines the limit of the slide–was observed to vary between 5 and 45 feet above the roadway grade.

5. The failed slope material was observed to be comprised of sand, cobbles, boulders, vegetation and was determined to have reached a state of equilibrium.

Representative photos of the failed slope may be referenced in Appendix G.

Project PRA-FOOT 8G14 consists of landslide repair within the slope failure limits along the Foothills Parkway. Work for this project includes stabilization and restoration of the slide area; drainage improvement and restoring the Parkway to its pre-slide condition within the limits of the slide.

GEOLOGIC SETTING

REGIONAL GEOLOGY

According to the United States Geological Survey's (USGS) *"Geologic Map of the Great Smoky Mountains Region (2005),"* the project site is located within the Lower Cambrian Chilhowee Group along the southern foothills of the Chilhowee Mountain. The rocks of the Chilhowee Mountain lie between the Great Smoky fault and the Miller Cove fault zones. Rocks within the vicinity of the project are predominantly units of Hess Formations, and to a lesser extent, the Helenmode Formation. The Hesse Formation within the project site is characterized by gray to white, coarse-to medium-grained greywacke and quartzose sandstone (arkose) in graded beds, interbedded with dark gray slate and siltstone.

The United States Department of the Interior's Geology of the Central Great Smoky Mountains Tennessee (1964) notes that the Hesse Formation "...forms massive ledges up to 10 ft or more thick, which break off in castellated crags and rounded boulders, characteristically pitted by cavities half an inch or less across..." Refer to Figure 2 of Appendix A, for a Geologic Map of the project area.

SOIL SURVEY

According to the United States Department of Agriculture, *"Soil Survey, Blount County Tennessee" (1959),* the project site is underlain predominantly by soils of the Tellico-Alcoa-Neubert Association, and to a lesser extent the Dandridge-Whitesburg-Hamblen Association. Both soil Associations are predominantly on hilly and steep slopes and consists of soils that are the product of the weathering of calcareous sandstone and sandy shale bedrock. The Tellico-Alcoa-Neubert soils are sandy and moderate-to well-drained, while Dandrige-Whitesburg-Hamblen soils are typically moderate-to poorly-drained. Soils are typically reddish-brown or brown and measure between 4 and 20-inches thick. Refer to Figure 3 of Appendix A, for a Soil Survey Map of the project area.

PROCEDURES AND RESULTS

GENERAL

The Eastern Federal Lands Highway Division's (EFLHD) Subsurface Exploration Team conducted a subsurface investigation program at the project site between January 17 and 18, 2007. The subsurface investigation program consisted of drilling a total of three (3) boreholes, designated B-1 through B-3, within the project limits with a CME 850 rotary, track-mounted drill rig. All borings were drilled adjacent to the ditch line along the toe of the slope. No borings were drilled within the failed slope or above the slide area due to NPS accessibility constraints and safety concerns. The characteristics of subsurface material within the failed slope limits were determined by visually observing and recording the type and nature of accumulated slide debris and material within the face of the failure. A Boring Location Plan and generalized Subsurface Profiles are provided in Appendix B.

SAMPLING

Boreholes were drilled to depths ranging from 3.0 to 24.4 ft below the existing ground surface. Borings were advanced to depth using 3 ¾ -in. (inside diameter) hollow stem flight augers. Standard Penetration Tests (SPT) were performed using a 2¼ -in. (outside diameter) split-spoon sampler in accordance with AASHTO 7200 and AASHTO T206.

Rock coring was completed in borings B-2 and B-3 only, upon encountering auger refusal. Rock coring was performed using rotary drilling techniques and samples were retrieved using a double-walled NQ wireline core barrel. Rock core samples were preserved in wooden boxes for laboratory testing.

All samples were later transported to EFLHD's Materials Testing Laboratory in Sevierville, Tennessee for laboratory testing and storage. The sampling sequence and associated jar samples for each boring are presented on its appropriate Boring Log in Appendix C.

FIELD TESTS AND MEASUREMENTS

Boring locations were determined from features present on-site and by referencing the existing roadway. Boring elevations were determined by extrapolation of topographic lines from site maps provided by EFLHD's Survey Section. SPT soil samples in the shallow borings were typically continuously recovered by driving the split-spoon sampler a distance of 24-in., or until refusal, into the undisturbed soil under the action of a 140-pound automatic hammer free-falling 30 inches. The number of hammer blows required to advance the split-spoon sampler the middle foot of the 24-in. sample interval is designated as the "Standard Penetration Resistance" or N-Value. Auger refusal is defined by 50 blows per 1-in. of penetration of the split-spoon sampler. The number of blows required to advance the sampler through each 6-in. interval was recorded on field boring logs. The relative consistency of each cohesive sample was estimated using a calibrated pocket penetrometer.

A field description by color and texture was made for each recovered sample. Percent core recovery (CR) and rock quality designation (RQD) were determined for each core run to provide a quantitative basis for evaluation of rock conditions.

Groundwater levels, if present, were measured in the boreholes at the time and under the conditions stated on boring logs.

DATA SUMMARY

The EFLHD Subsurface Investigation Team performed the following field tests and measurements during the course of the subsurface exploration. The results of field tests and measurements were recorded on the driller's logs and appropriate data sheets in the field. These data sheets and logs contain information concerning the boring methods; samples attempted and recovered; indications of the presence of various material such as gravel, pebbles, organic matter, etc.; and observations of groundwater. They also contain interpretations by the exploration team leader of the subsurface conditions based on the performance of the equipment and cuttings brought to the surface by the drilling tools. Therefore, the field data represents both factual and interpretative information.

The boring logs in Appendix C represent a compilation of field laboratory data and description of the soil samples by a geotechnical engineer. These records occasionally do not include all data recorded on the driller's logs and field data sheets, but do include all information considered relevant to the design and preparation of this report.

Groundwater level readings were made at the times and under the conditions stated on the boring logs.

FINDINGS

Boring logs describing the subsurface conditions encountered in each boring may be referenced in Appendix C. The approximate location of borings drilled and a generalized subsurface profile may be referenced in Appendix B. Descriptions of the soil conditions encountered during the subsurface explorations conducted at the site are presented below. The categories and descriptions below are indicative of the various types of subsurface soils encountered and does not suggest stratification.

Pavement – The pavement section within the slide limits generally consists of an approximate 0.4 ft (5-in.) thickness of asphalt concrete (AC). No base material was observed below the pavement section.

Decomposed Rock – The pavement section was observed to be underlain by decomposed sandstone. This stratum was observed to be comprised of light brown to tan, silty sand with relict rock structure. SPT N-values recorded within this stratum ranged between 9 and 50 blows per foot, indicating loose to very dense soil conditions. Thickness of this stratum was measured to vary between 1.5 and 3.2 ft.

Rock – Intact bedrock was encountered underlying the decomposed rock strata at depths varying between 2.2 and 3.2 feet below ground surface. This strata is characterized by very hard, gray-brown to red-gray, relatively sound to sound, weathered to unweathered quartzose sandstone (arkose). Rock core recoveries ranged from 96 to 100 percent, and RQD values ranged from 80 to 94 percent, indicating good to excellent rock quality.

Both Borings B-2 and B-3 were terminated within this stratum at an average depth of 20.4 ft. Photos of rock core samples recovered may be reference in Appendix G.

The groundwater table was not encountered in any of the borings drilled.

LABORATORY TESTING

Unconfined Compressive Strength laboratory testing was conducted on rock core samples recovered during our subsurface investigation. All tests were conducted in accordance with applicable AASHTO/ASTM standard test methods.

Laboratory test results are summarized in Table I and may be referenced in Appendix D.

Table 1 – Summary of Laboratory Test Results on Rock Core Samples

Boring No.	Core Run No.	Rock Core Depth (ft)	Rock Type	Unconfined Compressive Strength (psi)
B-2	1	7.8-9.4	Sandstone	10,080
B-2	2	10.8-12.6		8,720
B-3	2	5.6-8.0		7,240

DESIGN ANALYSES AND CONCLUSIONS

DESIGN ALTERNATIVES

A number of alternatives were considered for repair and stabilization of the failed slope. Of the alternatives considered the three presented below were further evaluated relative to each other on the basis of stability, cost, constructability, aesthetics and limits of disturbance, in order to determine the preferred alternative. The alternatives considered are as follows:

1. *Alternative No. 1* – The first alternative consists of repairing the failed slope by constructing a mechanically-placed rock embankment along the face of the existing slope, from the crest of the slide down to the roadway level. A mechanically-placed rock embankment generally consists of placing Class 3 or larger riprap along the face of the embankment using standard construction equipment.

2. *Alternative No. 2* – The second alternative consists of repairing the failed slope by constructing a geofabric-reinforced soil (GRS) slope along the face of the embankment from the toe of the slide up to the existing roadway level. A GRS is comprised of alternating layers of stabilization geofabric embedded within alternating layers of backfill soil.

3. *Alternative No*. 3 – This alternative consists of stabilizing the failed slope by removing the failed material; scaling and removing loose material from the face of the slide and rounding the crest of the slide, including selective clearing of trees. No fill material would be placed within the excavated area.

Based on the aforementioned factors and on consultation with the NPS, Alternative No. 1 was selected as the most suitable alternative for repairing the failed area. This alternative was determined to be the most cost effective option as the in-place broken rock could be reused for embankment construction. Additionally, it allows for practical and timely construction and provides a level of stability to the slide by acting as a buttress along the face of the slope failure.

ANALYSES

Stability of the proposed repair alternative was evaluated in accordance with principles presented in USDA EM-7170-14, *"Retaining Wall Design Guide."*(1994). Design computations were performed using the computer program ReSSA(2.0). The geometry of the critical slope section was obtained using drawings obtained from EFLHD's Highway Design Section. Coordinates were established for the highest slope section, generally along the centerline of the slide.

Design analyses indicate that the proposed rock embankment satisfies global stability requirements by exceeding the minimum required factor of safety of 1.3.

Design analysis computations may be referenced in Appendix E.

RECOMMENDATIONS

We recommend that the failed slope be repaired using a special rock embankment, constructed in accordance with Section 252 of the FP-03 Specifications, except as detailed herein. The rock embankment is to be constructed as follows:

1. The special rock embankment is to consist of native broken rock and imported rock fill, as needed. Imported rock should meet the requirements of Section 705 of the FP-03 Specifications.

2. The limits of repair are to extend a minimum of 5 ft (maximum of 10 ft) beyond the limits of the slide area.

3. Subexcavate a “toe” area along the edge of the ditch line that measures a minimum of 3.0 ft deep and with a bottom dimension that is a minimum of 5.0 ft wide.

4. Bench the back of the excavation to provide benches that are a maximum of 10 ft high and measure a minimum of 10 ft horizontally. The first bench, extending from the toe of the slope back, is to be a minimum of 20 ft wide. Grade the bottom of all benches on a 10 percent negative slope toward the underdrains along the back of the benches.

5. Provide underdrains along the backside of benches that are comprised of a 6-in. diameter underdrain encapsulated in granular backfill material by a Type 1-E geotextile. Underdrain is to conform to the minimum dimensions provided on EFLHD Detail E605-A.

6. Flush the rock face with gravel (#57 stone) and a minimum of 12-in. of on-site excavated soil. Place a minimum of 4-in. of topsoil and seed along the face of the slope. Seeding should be in accordance with NPS recommendations.

The height of the proposed embankment varies to a maximum of approximately 30 ft; and is to be constructed to match the existing topography as much as possible.

A typical repair detail is provided in Appendix G.

CONSTRUCTION CONSIDERATIONS

Rock – Wherever possible, use native rock found within the project limits. Furnished rock is to conform to Section 704 of the FP-03. Do not use rock with depressions of projections that might weaken it or prevent it from being properly embedded.

Subsurface Drainage – An underdrain system is to be installed along the back face of all benches in accordance with Detail E605-A. To facilitate drainage along the benches, grade benches gently towards the back face of the excavation at a slope of approximately 10(h):1(v).

The underdrain system should have a 6-inch diameter perforated collector pipes. The collector pipes should be wrapped with Type II-C nonwoven geotextile conforming to Section to 714 of the FP-03. Collector pipes should be graded to drain to the end of the slope repair, where the water may be removed through an outlet pipes or are to discharge along the slope a minimum of 5.0 feet beyond the limits of repair slope. Collector pipes and outlet pipes should be placed on a minimum 2% slope.

DISCLAIMER/LIMITATIONS CLAUSE

The subsurface explorations and tests described in the section on Procedures and Results have been conducted in accordance with standard practices and procedures (except as specifically noted). The results of these explorations and tests represent conditions at the specific locations indicated. Subsurface conditions between these locations may vary. The Analysis and Conclusions section and the Recommendations section in this report include interpretations and recommendations developed by the Government in the process of preparing the design. These interpretations are not intended as a substitute for the personal investigation, independent interpretation, and judgment of the Contractor.

Prepared by:
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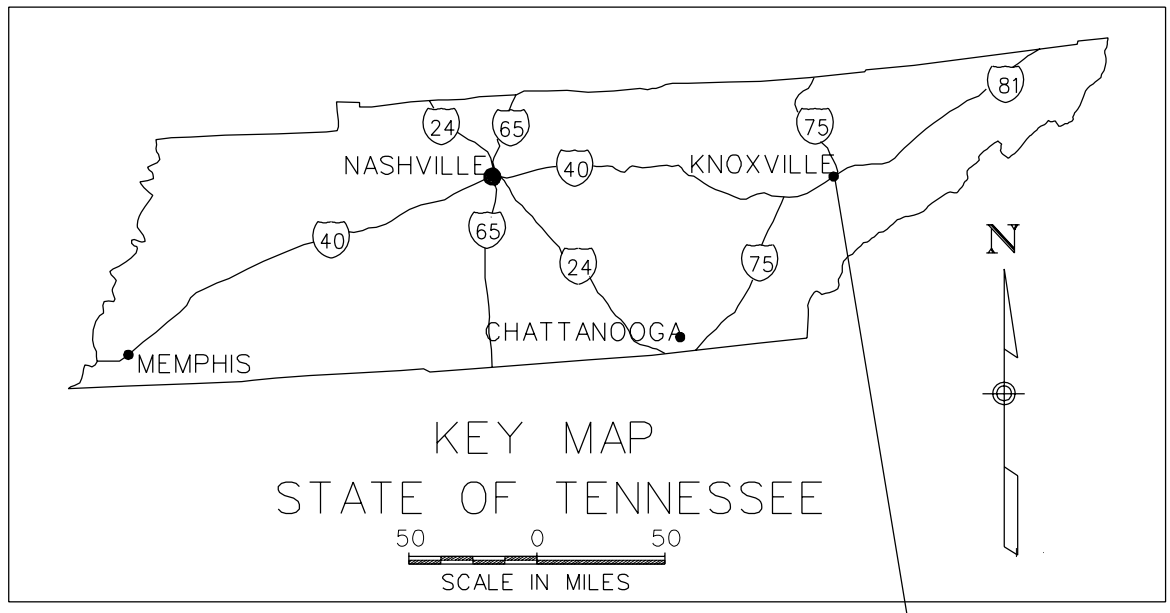
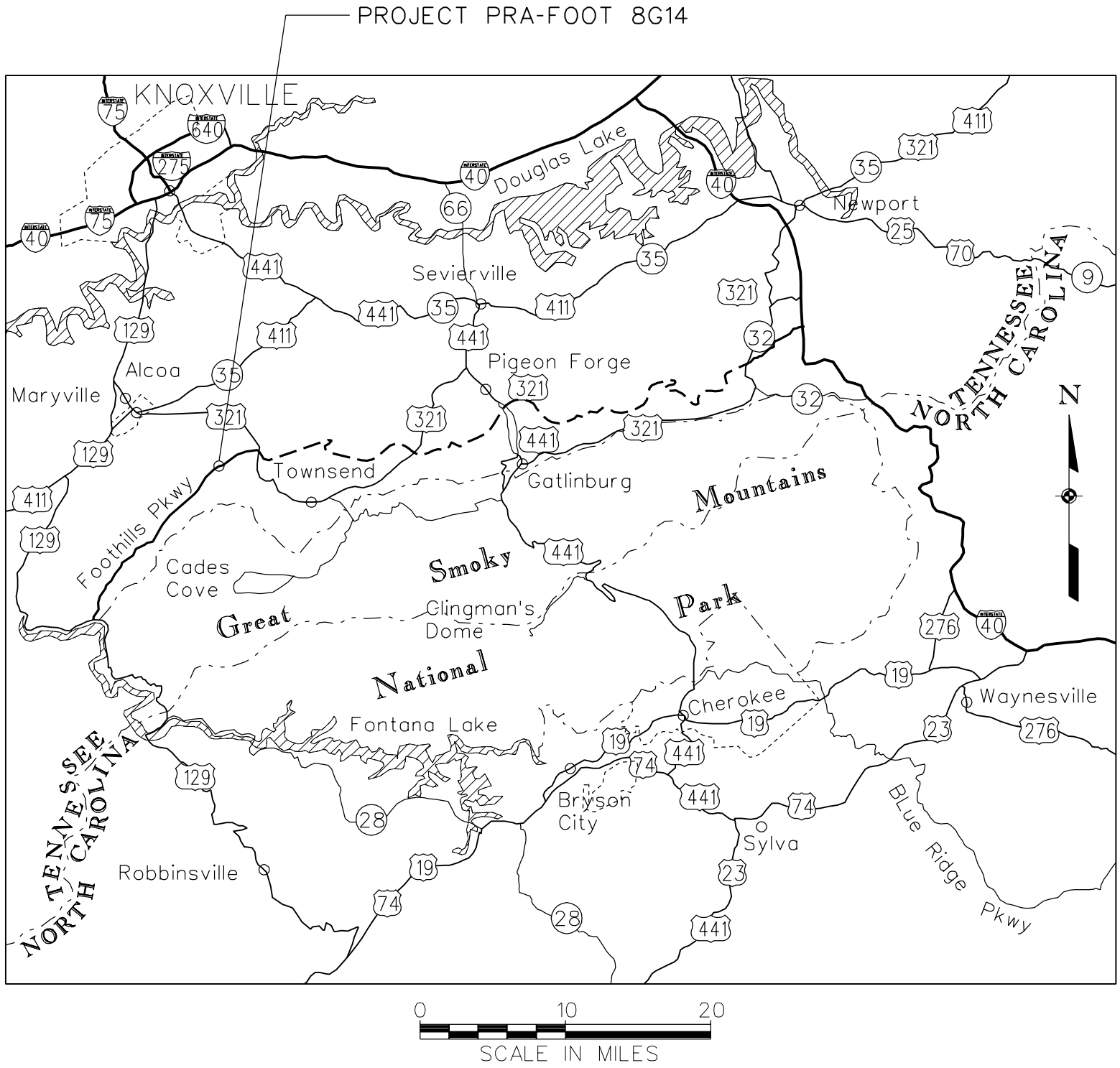
APPENDIX A

Figures





U.S. DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION EASTERN FEDERAL LANDS HIGHWAY DIVISION STERLING, VIRGINIA	FOOTHILLS PARKWAY SITE LOCATION AND VICINITY MAP FIGURE 1	REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
		SE	TN	PRA-FOOT 8G14	1	3

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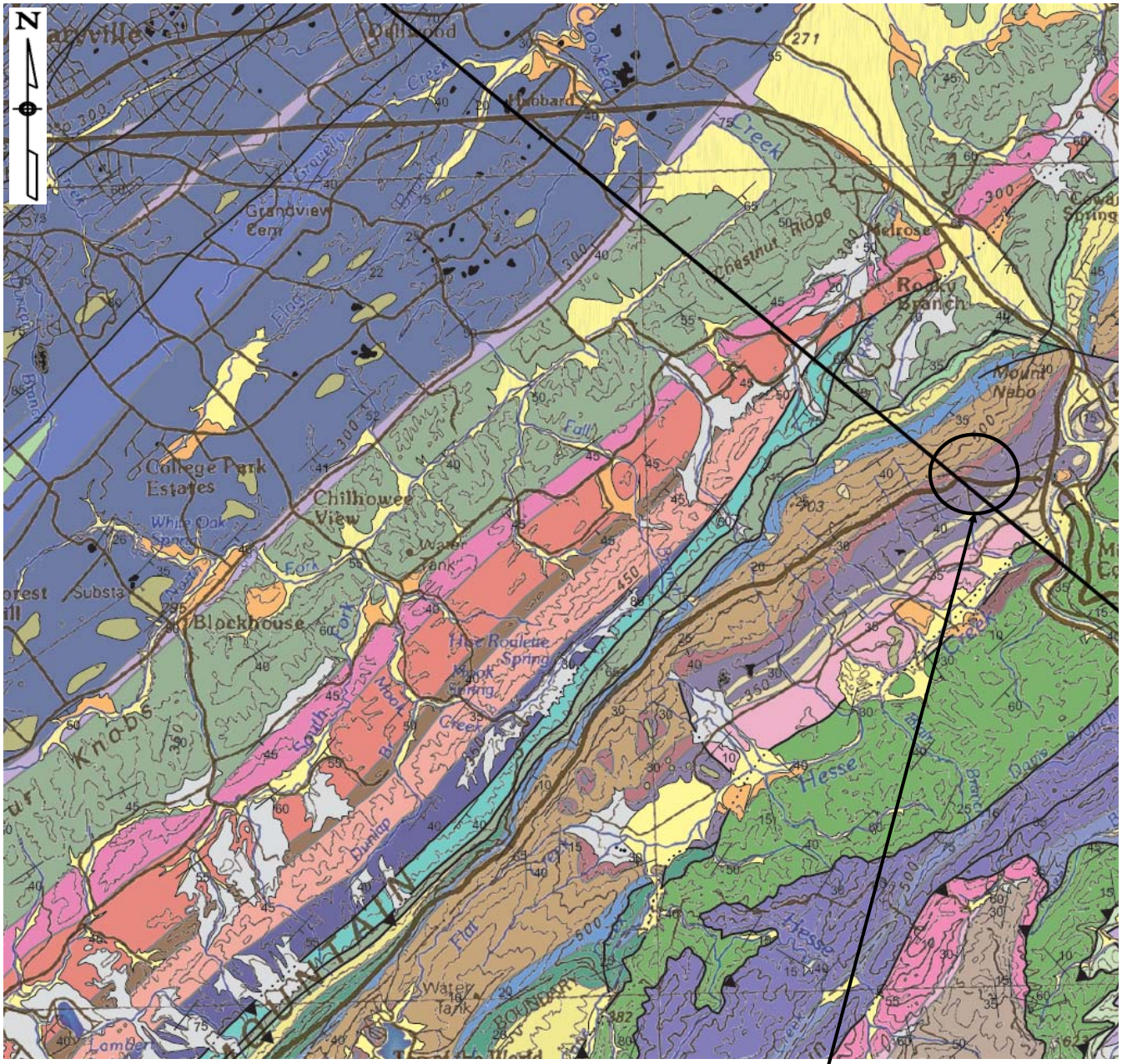


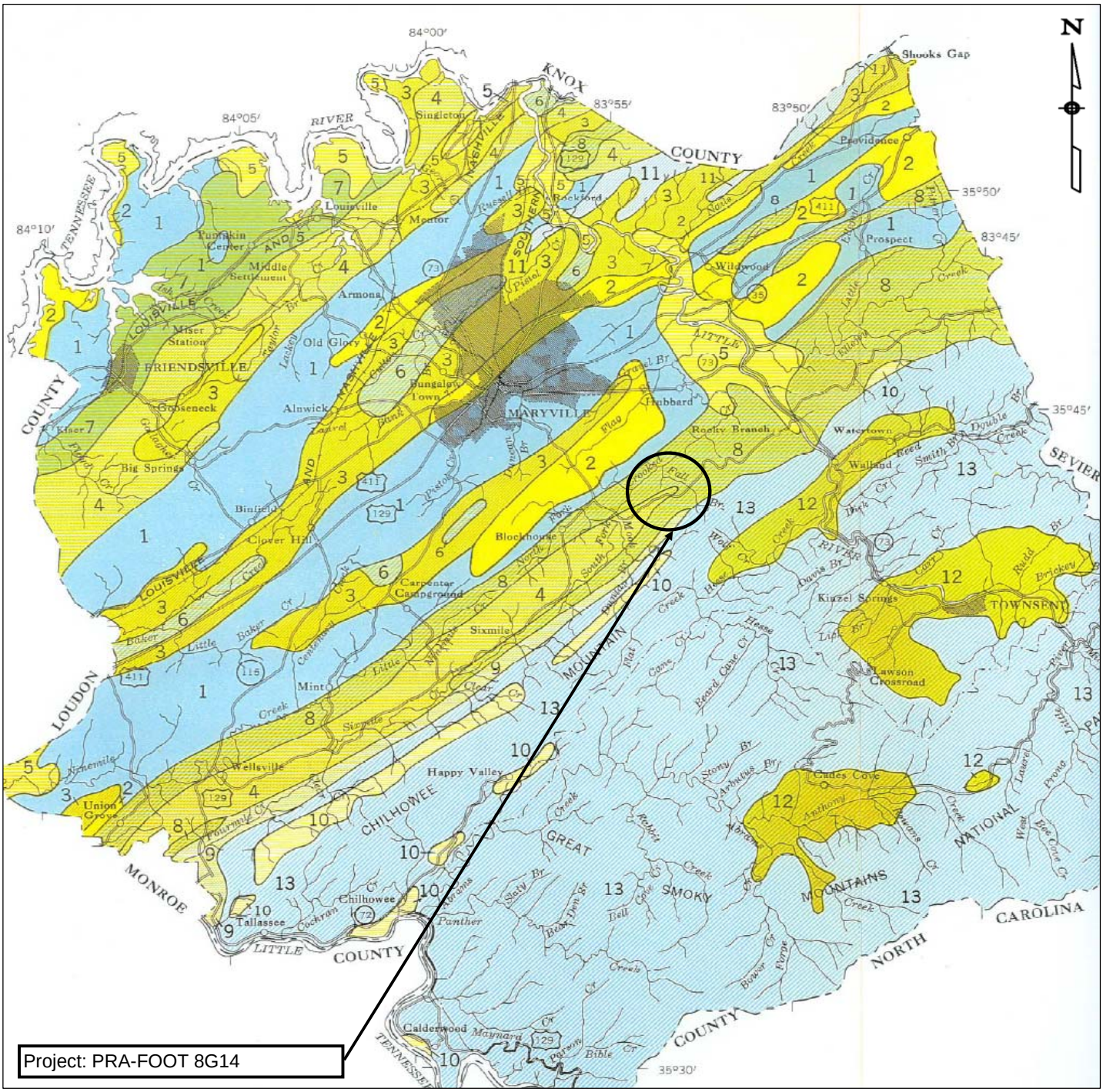
Ch — HELENMODE FORMATION
Gray, micaceous shale containing beds of coarse sandstone

Chm — HESS FORMATION
Thick-bedded white quartzite; weathers to

Cs — SHADY DOLOMITE
Thick-bedded dolomite containing shaly dolomite

Source:
Geologic Map of the Great Smoky Mountains Nation Park Region (2005)
United States Geological Survey

U.S. DEPARTMENT OF TRANSPORTATION FEDERAL LANDS HIGHWAY DIVISION EASTERN FEDERAL LANDS HIGHWAY DIVISION STERLING, VIRGINIA	**FIGURE 2** GEOLOGIC MAP	REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
		SE	TN	PRA-FOOT 8G14	2	3



4

TELLICO-ALCOA-NEUBERT

Hilly to steep soils, many of whichare relatively shallow to the calcareous sandstone or sandy shale bedrock. They are reddish, sandy and permeable

8

DANDRIDGE-WHITESBURG-HAMBLEN

Predominantly steep and consists of soils that are shallow to calcareous shale bedrock. Soils are moderate to poorly draining.

Source

Soil Survey of Bloutn County Tennessee (1959)

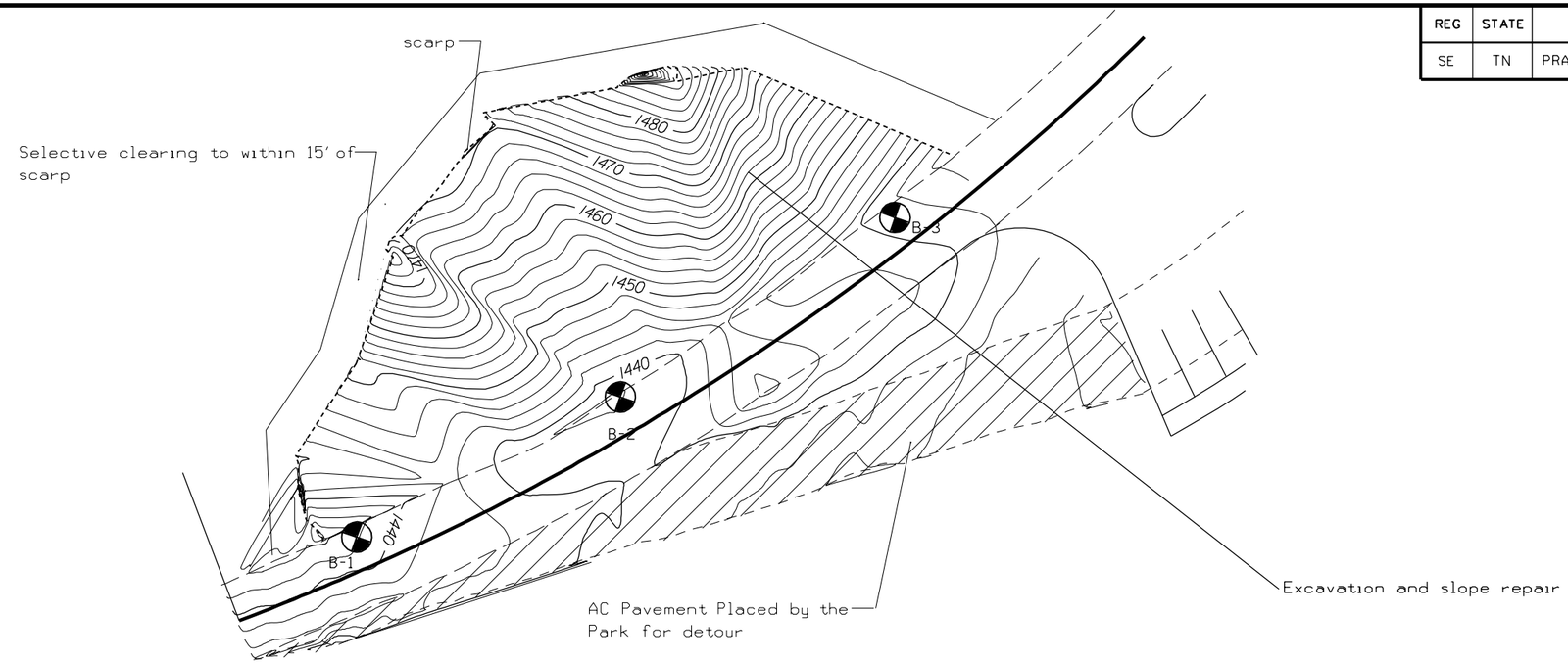
United States Department of Agriculture

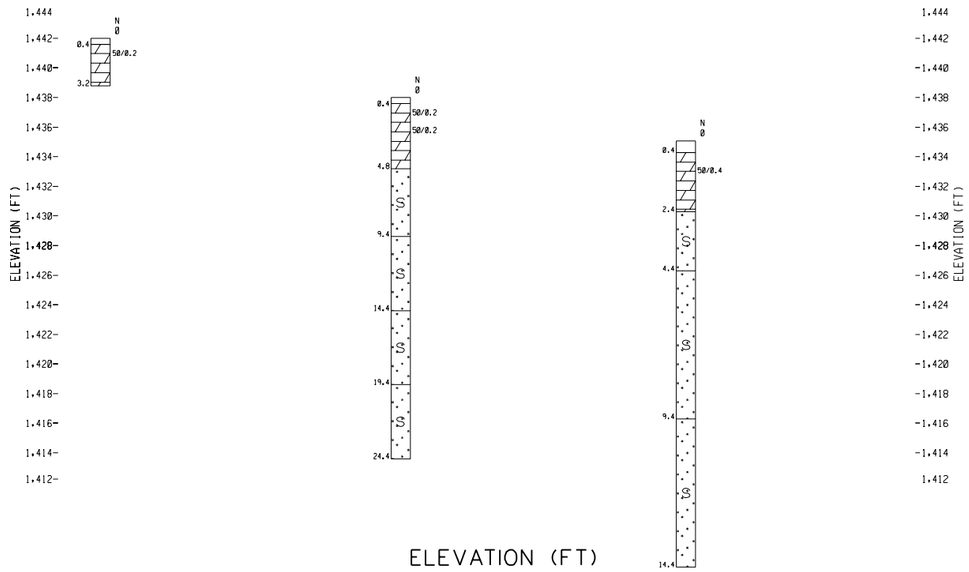
U.S. DEPARTMENT OF TRANSPORTATION FEDERAL LANDS HIGHWAY DIVISION EASTERN FEDERAL LANDS HIGHWAY DIVISION STERLING, VIRGINIA	**FIGURE 3** SOIL SURVEY MAP	REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
		SE	TN	PRA-FOOT8G14	3	3

APPENDIX B

Boring Logs and Subsurface Profile

REG	STATE	PROJECT	SHEET NO.	TOTAL SHEETS
SE	TN	PRA-FOOT 8G14	1	1





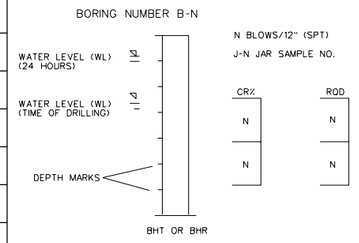
LEGEND:

APPROXIMATE LOCATION OF BORINGS DRILLED BY EFLHD

THE BORING LOGS ON THIS SHEET REPRESENT THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE BORING LOCATIONS SHOWN. SUBSURFACE CONDITIONS MAY VARY BETWEEN THESE LOCATIONS.

SYMBOL	TYPE OF MATERIAL	SYMBOL	TYPE OF MATERIAL
	FILL		
	DECOMPOSED ROCK		
S	SANDSTONE		

TEST BORING



MISCELLANEOUS

1. SPT - STANDARD PENETRATION TEST - AASHTO T206-74
2. R - REFUSAL, SPT 100 BLOWS/12"
3. CR% - PERCENT OF RECOVERY
4. RQD - ROCK QUALITY DESIGNATION
5. BHT - BORE HOLE TERMINATED
6. BHR - BORE HOLE REFUSAL
7. GEOPHYSICAL TEST SITE: SEISMIC S RESISTIVITY R

SCALE

NOT TO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION
STERLING, VIRGINIA

BORING LOCATION PLAN AND SUBSURFACE PROFILE

PROJECT PRA-FOOT 8G14
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APPENDIX C

Boring Logs

SOIL BORING GENERAL NOTES

Drilling and Sampling Symbols

SS: Split Spoon - 1 3/8" I.D., 2" O.D., except where noted
ST: Shelby Tube - 2" O.D., except where noted
PA: Power Auger Sample

Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious soils, the indicated elevations are considered reliable ground water levels. In impervious soils, the accurate determination of ground water elevations is not possible, even after several days, and additional evidence on ground water elevations must be sought.

VISUAL METHODS FOR SOILS CLASSIFICATION

Component	Distinguishing Features
Boulders	Larger than 12" (300 mm)
Cobbles	3" to 12" (75 mm to 12 mm)
Gravel	Larger than No. 4 sieve and smaller than a 3" sieve, described with any of the following terms (or any combination):
Coarse	3" to 3/4" (75 mm to 19 mm) sieve
Medium	3/4" to 3/8" (19 mm to 9.5 mm) sieve
Fine	3/8" to No. 4 (9.5 mm to 4.75 mm) sieve
Sand	The finest sand grains are just visible to the naked eye, while the largest would pass a No. 4 (4.75mm) sieve (pinhead size). Described with any of the following terms (or any combination):
Coarse	No. 4 to No. 10 (4.75 mm to 2.0 mm) sieve
Medium	No. 10 to No. 40 (2.0 mm to 0.42 mm) sieve
Fine	No. 40 to No. 200 (0.42 mm to 0.075 mm) sieve
Silt	1. Lumps are easily crumbled when are-dried. 2. Feels gritty between the teeth. 3. A moist pat when shaken in the palm of the hand will appear shiny and wet. When squeezed it will appear dry and dull.
Clay	1. Lumps are comparatively hard when air-dried. 2. Threads (1/8" diameter) of considerable length will support their own weight when held by one end. 3. A moist pat will appear the same whether shaken in the palm of the hand or squeezed.

Order of Description

1. Soil Density (or consistency) – see table below
2. Color
3. Major Grain Size – Composes more than 50% of the sample
4. Modifying Term – "and" : 40% to 50% of the minor grain size
   "some" : 30% to 40%
   "little" : 10% to 30%
   "trace" : 10% or less
5. Minor Grain Size(s)
6. Other (plasticity, etc.)

7. Moisture Content (by field test) – "dry" : Absence of moisture, dusty, dry to the touch
"moist" : Damp but no visible water
"wet" : Visible free water, usually soil is below water table
8. General Classification – Fill, Residual Soil, Weathered Rock

SOIL DENSITY (OR CONSISTENCY) TABLE			
Coarse-Grained Soil (Gravel, Sand)		**Fine-Grained Soil (Clay, Silt)**	
Apparent Density	SPT (# blows / ft)	Consistency	SPT (# blows / ft)
Very loose	0-4	Very soft	0-2
Loose	5-10	Soft	3-4
Medium dense	11-30	Medium stiff	5-8
Dense	31-50	Stiff	9-15
Very dense	>50	Very stiff	16-30
		Hard	>30

Examples:

1. Loose, brown to light brown **SILT** and **SAND**, trace clay
(moist)
-FILL-

Criteria for Describing Soil Structure

Description	Criteria
Bed	A sedimentary layer bounded by depositional surfaces.
Blocky	A characteristic in which cohesive soil can be broken down into small angular lumps which resist further breakdown.
Bonded	Attached or adhering.
Fissured	Broken along definite planes of fracture.
Foliated	Planar arrangement of textural or structural features.
Frequent	More than one per foot of thickness.
Homogeneous	Same color and appearance throughout.
Interbedded	Alternating soil layers of different composition.
Laminae	A very thin cohesive layer.
Layer	A general term for material lying essentially parallel to the surfaces against which it was formed.
Lens	A lenticular deposit, larger than a pocket.
Occasional	One or less per foot of thickness.
Parting	A very thin granular layer.
Pocket	Small erratic deposits less than 12" in thickness.
Seam	A thin layer separating two distinctive layers of different composition or greater magnitude.
Stratified	Alternating layers of varying material or color.
Stratum	A stratigraphic unit.
Varve	A cyclic sedimentary couplet consisting of a coarser and a finer layer representing the variation in depositional energy resulting from the annual freeze-thaw cycle typically found in glaciolacustrine environments.

ROCK CORING GENERAL NOTES

Depth and Elevation: Use large marks as 1' (300mm) increments. Record proper elevations.

Core: Draw sketch of core breaks as it is oriented in the core box (align all core breaks so they fit together properly before drawing sketch). Starting at the top of core measure each piece of core down its centerline to 1/100 of a foot. Record this measurement along the left side of the core sketch at the break.

VISUAL METHODS FOR ROCK IDENTIFICATION

Description:

1. Draw a heavy line through description at depth to which core run penetrated.
2. Describe the rock type.
3. Note the condition of the core break on the right side of the core sketch
   Mud seam (MS); Sand seam (SS); Weathered surface (WS); Fresh break (FB)
4. Record coring time in minutes.
5. Record to nearest 1/100 foot the core recovered (after alignment in core box). Discard any debris at top of core, which obviously fill into the core hole.
6. Calculate per cent core recovery and record: $CR = \frac{\text{feet of core recovered}}{\text{feet cored}}$

Color: Wet the rock with water and describe the color including the color of any unusual or reoccurring markings on the core (i.e. light green with dark green bands, foliation lines).

Foliation: Foliation planes are parallel planes of different minerals forming a banded appearance on the rock. The foliation planes are usually of a different color than the surrounding rock. Also the rock shears along the foliation planes if struck with a hammer. Record the following:

Close spaced (CS) – 1/8" (3mm) or closer; Medium spaced (MS) – 1/8" to 1/4" (3mm to 6mm); Open spaced (OS) – 1/4" (6mm) or larger

The angle to the horizontal should be measured (with a protractor) and recorded for the rock core. (Several different angles can be found in each 5' to 10' core.)

Hardness: Very Soft (VS) – Can be deformed or crumbled by hand; Soft (S) – Can be scratched with a fingernail
Moderately Hard (MH) – Can be scratched easily with a knife; Hard (H) – Can be scratched with difficulty with a knife; Very hard (VH) – Cannot be scratched with a knife

Weathering: Use the proper number 1 through 5.

1. Unweathered: No evidence of any mechanical or chemical alteration along discoloration evidenced.
2. Slightly weathered: Discoloration is evident, on surface, slight alteration no discontinuities, less than 10% of the volume is altered, strength is substantially unaffected.
3. Moderately weathered: Discoloring is evident, surface is pitted and altered with alteration penetrating will below rock surfaces, weathering "halos" evident, 10% to 50% of the rock is altered, strength is noticeably less than fresh rock.
4. Highly weathered: Entire mass is discolored; alteration pervades nearly all of the rock with some pockets of slightly weathered rock noticeable, some minerals leached away, retains only a fraction of original strength (with wet strength usually lower than dry strength).
5. Decomposed: Rock is reduced to a soil with relict rock structure (saprolite), can be generally molded and crumbled by hand.

Rock Quality Designation (RQD) $= \frac{\Sigma[\text{Lengths of all pieces of the core} \geq 4\text{" (100mm)}]}{\text{Total length of core run}} \times 100$

Soundness: Use the proper number 1 through 5

1.	Weathered	RQD = 0% to 25%
2.	Highly jointed to Jointed	RQD = 25% to 50%
3.	Jointed to Relatively sound	RQD = 50% to 75%
4.	Relatively sound to Sound	RQD = 75% to 100%

Rock Quality: Use the proper number 1 through 5

1.	Very Poor	RQD = 0% to 25%
2.	Poor	RQD = 25% to 50%
3.	Fair	RQD = 50% to 75%
4.	Good	RQD = 75% to 90%
5.	Excellent	RQD = 90% to 100%

Order of Description

1. Hardness
2. Color
3. Soundness (a.k.a. Weathering and Rock Quality)
4. Main Rock Formation – Composes more than 50% of the core run
5. Texture – Very Fine (VF), Fine (F), Medium (M), and Coarse (C)
6. Modifying Term – "and" : 40% to 50% of the core run
   "some" : 30% to 40%
   "little" : 10% to 30%
   "trace" : 10% or less
7. Minor Rock Type(s)
8. Other (Foliation angle, etc.)

Examples:

1. Moderately hard, blue-gray to gray, weathered **BIOTITE GNEISS BOULDER**, medium texture

   Recovery = 24%
   RQD = 17%

2. Very hard, gray and white, relatively sound to sound **BIOTITE GNEISS**, medium to fine texture, some quartz veins, foliation angle = 20 degrees

   Recovery = 100%
   RQD = 100%

   -Fresh break @ approximately 47'

BORING LOG

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION

Project Name: PRA-FOOT 8G14 | Boring No.: B-1 | Sheet: 1 of 1

Project Location: Foothills Parkway, Blount County, TN | Boring Location: Edge of Pavement @ Southern Limit of Slide

Groundwater Depth:
Encountered at: ▽
At Completion: ▼
After ____ hrs ▼

Surface Elevation: 1442.0 ft
Caved at: ▽
Hammer Wt. & Type: 140 lbs/Auto
Hammer Drop: 30 in.

Boring Began: 1/17/07 | Completed: 1/17/07
Boring Method: HSA | Inspector: A. Anderson
Hole Diameter: 3 3/4 | Operator: B. Kingsley/D. Hutchins
Rock Core Diam: N/A | Weather: Cloudy 28-33 ºF

Elevation (feet)	Graphic Log	Layer Depth (ft)	MATERIAL DESCRIPTION Density, Color, Plasticity, Size, Proportions, Moisture	Depth Scale (ft)	SAMPLE Type	SAMPLE No.	SAMPLE Rec.	SAMPLE Blows per 6 in.	Water Content % / Standard Penetration Test Data (Blows / ft)
1441.6		0.4	**Asphalt Pavement**						
			Very dense, tan to yellow-brown, fine to medium, **silty SAND**, relict rock structure			J-1	1.0	17-43-50/0.2	6.24317"
			-DECOMPOSED ROCK-						
1438.8		3.2							
			Borehole Terminated @ 3.2 ft						
				5					
				10					
				15					
				20					
				25					

Plastic Limit ⊢——⊣ Liquid Limit
10 20 40 60 80

Sample Types:
- Auger Cuttings
- Vane Shear
- SPT
- UD
- Penetrometer
- Rock Core

Remarks:
1. Borehole terminated upon encountering auger refusal
2. Groundwater table was not encountered

BORING LOG PRA-FOOT 8G14.GPJ FHWA_VA.GDT 4/1/08

BORING LOG

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION

Project Name: PRA-FOOT 8G14 | Boring No.: B-2 | Sheet: 1 of 1

Project Location: Foothills Parkway, Blount County, TN | Boring Location: Edge of Pavement @ Approximate Centerline of Slide

Groundwater Depth:
Encountered at: ▽
At Completion: ▼
After ____ hrs ▼

Surface Elevation: 1438.0 ft
Caved at: ▽
Hammer Wt. & Type: 140 lbs/Auto
Hammer Drop: 30 in.

Boring Began: 1/17/07 | Completed: 1/17/07
Boring Method: HSA | Inspector: A. Anderson
Hole Diameter: 3 3/4 | Operator: B. Kingsley/D. Hutchins
Rock Core Diam: NQ | Weather: Cloudy 28-33 ºF

Elevation (feet)	Graphic Log	Layer Depth (ft)	MATERIAL DESCRIPTION Density, Color, Plasticity, Size, Proportions, Moisture	Depth Scale (ft)	SAMPLE Type	No.	Rec.	Blows per 6 in.	Water Content % / Standard Penetration Test Data (Blows / ft)
1437.6		0.4	**Asphalt Pavement**						
			Very dense, tan to yellow-brown, fine to medium **silty SAND**, relict rock structure						
						J-1	1.3	9-26-50/0.2	6.2269"
						J-2	0.2	50/0.2	0.2"
			-DECOMPOSED ROCK-						
1433.2		4.8		5					
			Very hard, gray-brown to olive-gray, moderately weathered to unweathered, relatively sound to sound, **SANDSTONE**, fine texture, occasional clay seams, occasional quartz veins						
						R1	4.6		
			Recovery = 98% RQD = 82%						
1428.6		9.4		10					
			Same as Above						
			Recovery = 100% RQD = 94%			R2	5.0		
1423.6		14.4		15					
			Same as Above						
			Recovery = 96% RQD = 80%			R3	5.0		
1418.6		19.4		20					
			Same as Above						
			Recovery = 100% RQD = 84%			R4	5.0		
1413.6		24.4		25					
			Borehole Terminated @ 24.4 ft						

Water Content %: Plastic Limit ⊢——⊣ Liquid Limit
Standard Penetration Test Data (Blows / ft): 10 20 40 60 80

Sample Types:
- Auger Cuttings
- Vane Shear
- SPT
- UD
- Penetrometer
- Rock Core

Remarks:
1. Coring began upon encountering auger refusal on rock @ 4.8 ft
2. Groundwater table was not encountered

BORING LOG PRA-FOOT 8G14.GPJ FHWA_VA.GDT 4/1/08

BORING LOG

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION

Project Name: PRA-FOOT 8G14 | Boring No.: B-3 | Sheet: 1 of 1

Project Location: Foothills Parkway, Blount County, TN | Boring Location: Edge of Pavement @ Northern Limit of Slide

Groundwater Depth:
Encountered at: ▽
At Completion: ▼
After ____ hrs ▼

Surface Elevation: 1435.0 ft
Caved at:
Hammer Wt. & Type: 140 lbs/Auto
Hammer Drop: 30 in.

Boring Began: 1/8/07 | Completed: 1/8/07
Boring Method: HSA | Inspector: A. Anderson
Hole Diameter: 3 3/4 | Operator: B. Kingsley/D. Hutchins
Rock Core Diam: NQ | Weather: Cloudy 28-33 ºF

Elevation (feet)	Graphic Log	Layer Depth (ft)	MATERIAL DESCRIPTION Density, Color, Plasticity, Size, Proportions, Moisture	Depth Scale (ft)	SAMPLE Type	No.	Rec.	Blows per 6 in.	▼ Water Content % Plastic Limit ⊢——⊣ Liquid Limit ● Standard Penetration Test Data (Blows / ft) 10 20 40 60 80
1434.6		0.4	**Asphalt Pavement**						
			Very dense, gray-brown, fine to coarse **silty SAND**, some fine to coarse gravel, frequent cobbles			J-1	1.3	9-26-50/0.4	6.4269"
1432.6		2.4	-DECOMPOSED ROCK-						
			Very hard, red-gray, weathered, **SANDSTONE**, fine texture, occassional clay seams			R1	2.0		
1430.6		4.4	Recovery = 100% RQD = 17%	5					
			Very hard, gray-brown, moderately weathered to unweathered, relatively sound to sound, **SANDSTONE**, fine texture, occasional clay seams, occasional quartz veins			R2	5.0		
1425.6		9.4	Recovery = 100% RQD = 84%	10					
			Same as Above			R3	5.0		
			Recovery = 100% RQD = 84%						
1420.6		14.4	Borehole Terminated @ 14.4 ft	15					
				20					
				25					

Sample Types:
- Auger Cuttings
- Vane Shear
- SPT
- UD
- Penetrometer
- Rock Core

Remarks:
1. Coring began upon encountering auger refusal on rock @ 2.5 ft
2. Groundwater table was not encountered

BORING LOG PRA-FOOT 8G14.GPJ FHWA_VA.GDT 4/1/08

APPENDIX D

Laboratory Test Results

U.S. Department of Transportation
Federal Highway Administration
Federal Lands Highway Office

Eastern Federal Lands Highway Division
Materials Testing Laboratory
112 Industrial Park, Sevierville, TN 37862

State: TN
Project Number: PRA-FOOT 8G14 **County:** Blount
Sample Type: Rock Core
Sampled By: Geotech
Field Sample No: B-2/R-1
Submitted By: A. anderson
Boring No: B-2 **Sample No:** R-1 **Depth:** 7.8-9.4

Unconfined Compressive Strength of Intact Rock Core (ASTM 2938)

Unconfined Compressive Strength, psi	10080

Charles W. McCown, Jr. - Laboratory Team Leader — Date

U.S. Department of Transportation
Federal Highway Administration
Federal Lands Highway Office

Eastern Federal Lands Highway Division
Materials Testing Laboratory
112 Industrial Park, Sevierville, TN 37862

State: TN
Project Number: PRA-FOOT 8G14 **County:** Blount
Sample Type: Rock Core
Sampled By: Geotech
Field Sample No: B-2/R-2
Submitted By: A. anderson
Boring No: B-2 **Sample No:** R-2 **Depth:** 10.8-12.6

Unconfined Compressive Strength of Intact Rock Core (ASTM 2938)

Unconfined Compressive Strength, psi	8720

Charles W. McCown, Jr. - Laboratory Team Leader — Date

U.S. Department of Transportation
Federal Highway Administration
Federal Lands Highway Office

Eastern Federal Lands Highway Division
Materials Testing Laboratory
112 Industrial Park, Sevierville, TN 37862

State: TN
Project Number: PRA-FOOT 8G14 **County:** Blount
Sample Type: Rock Core
Sampled By: Geotech
Field Sample No: B-3/R-2
Submitted By: A. anderson
Boring No: B-3 **Sample No:** R-2 **Depth:** 5.6-8.0

Unconfined Compressive Strength of Intact Rock Core (ASTM 2938)

Unconfined Compressive Strength, psi	7240

Charles W. McCown, Jr. - Laboratory Team Leader — Date

APPENDIX E

Design Analysis Computations

FOOTHILLS PARKWAY LANDSLIDE REPAIR

PROJECT IDENTIFICATION

Title:	FOOTHILLS PARKWAY LANDSLIDE REPAIR
Project Number:	PRA - FOOT 8G14
Client:	THE NATIONAL PARK SERVICE
Designer:	A.Anderson

Description:

Company's information:

Name:	FEDERAL HIGHWAY ADMINISTRATION
Street:	Eastern Federal Lands Highway Division 21400 Ridgetop Circle Sterling, VA 20166
Telephone #:	(571) 404-6352
Fax #:	(571) 404-6217
E-Mail:	Andre.Anderson@fhwa.dot.gov

Original file path and name: M:\Projects\foot\8g14\techserv\geotech\Analysis\ReSSA1.MSE
Original date and time of creating this file: Fri Feb 29 12:31:38 2008

PROGRAM MODE: ANALYSIS of a Complex Slope using NO reinforcement material.

INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

=========== Soil Layer #: ===========	Unit weight, γ [lb/ft ³]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ²]
....1.......Special Rock Embankment...................	144.0	38.0	0.0
....2.......Sandstone Rock....................................	150.0	44.0	2000.0

REINFORCEMENT

Analysis of slope WITHOUT reinforcement.

WATER

Water is not present

SEISMICITY

Not Applicable

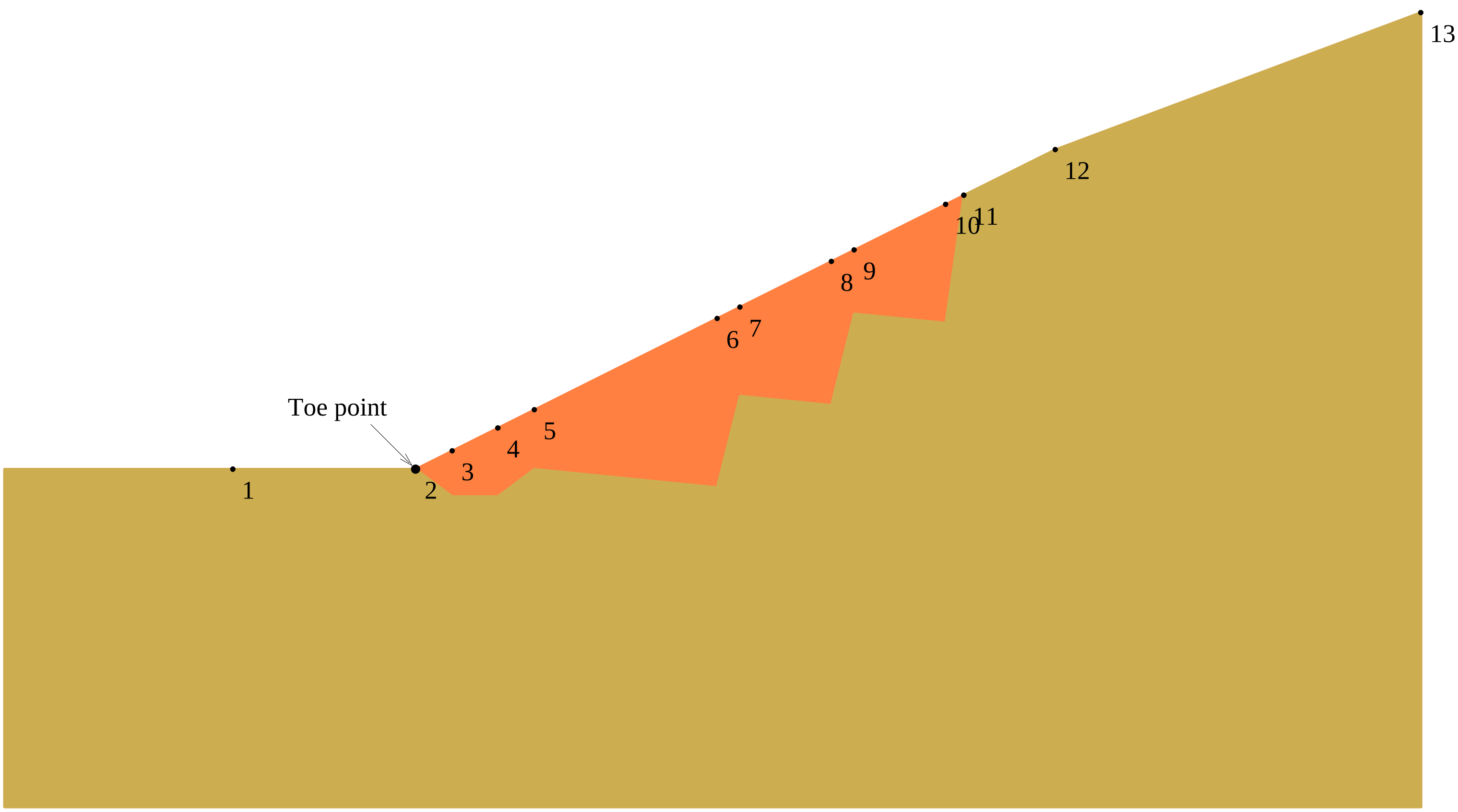
DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Quick Input

-- Problem geometry is defined along sections selected by user at x,y coordinates.
-- X1,Y1 represents the coordinates of soil surface. X2,Y2 represent the coordinates of the end of soil layer 1 and start of soil layer 2, and so on.

GEOMETRY
Soil profile contains 2 layers (see details in next page)

UNIFORM SURCHARGE
Surcharge load, Q1....................................None
Surcharge load, Q2....................................None
Surcharge load, Q3....................................None

STRIP LOAD
............................None..................................



SCALE:

0 2 4 6 [ft]

Version 2.0 ReSSA Version 2.0

TABULATED DETAILS OF QUICK SPECIFIED GEOMETRY

Soil profile contains 2 layers. Coordinates in [ft.]

	#	Xi	Yi
Top of Layer 1	1	320.00	400.00
	2	340.00	400.00
	3	400.00	430.00
	4	410.00	435.00
	5	450.00	450.00
Top of Layer 2	6	320.00	400.00
	7	340.00	400.00
	8	344.00	397.00
	9	349.00	397.00
	10	353.00	400.00
	11	373.00	398.00
	12	375.50	408.00
	13	385.50	407.00
	14	388.00	417.00
	15	398.00	416.00
	16	400.00	430.00
	17	410.00	435.00
	18	450.00	450.00

TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 2 layers. Coordinates in [ft.]

#	X	Y1	Y2
1	320.00	400.00	400.00
2	340.00	400.00	400.00
3	344.00	402.00	397.00
4	349.00	404.50	397.00
5	353.00	406.50	400.00
6	373.00	416.50	398.00
7	375.50	417.75	408.00
8	385.50	422.75	407.00
9	388.00	424.00	417.00
10	398.00	429.00	416.00
11	400.00	430.00	430.00
12	410.00	435.00	435.00
13	450.00	450.00	450.00

RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	356.40	408.20	339.98	399.99	-67.61	1235.71	929.82	1.56	
2	363.76	411.88	339.91	399.96	-250.49	1610.67	1347.00	1.56	
3	371.12	415.56	339.87	399.94	-433.37	1985.64	1764.18	1.56	
4	378.48	419.24	339.93	399.97	-616.25	2360.60	2181.36	1.56	OK
5	385.83	422.92	339.84	399.92	-799.13	2735.56	2598.54	1.56	
6	393.19	426.60	339.60	399.81	-982.01	3110.52	3015.73	1.56	
7	400.56	430.28	339.33	399.86	312.01	531.68	134.62	1.72	
8	407.92	433.96	339.54	399.95	328.70	507.50	108.09	2.60	
9	415.28	436.98	339.68	399.95	317.77	540.37	142.12	3.31	
10	422.64	439.74	339.86	399.99	328.69	529.32	129.82	3.83	
11	430.00	442.50	340.00	400.00	316.68	565.93	167.56	4.18	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

****

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	299.87	400.09	430.00	442.50	347.86	473.69	87.87	6.25	
2	303.36	400.17	400.56	430.28	328.43	491.19	94.40	6.04	
3	307.48	400.12	407.92	433.96	330.54	497.65	100.22	5.70	
4	311.88	400.03	400.56	430.28	331.93	486.35	88.62	5.02	
5	315.86	400.03	400.56	430.28	334.70	480.99	83.12	4.51	
6	319.82	400.04	400.56	430.28	336.61	478.13	79.87	4.03	
7	323.22	400.14	400.56	430.28	337.65	477.42	78.61	3.58	
8	327.57	400.06	400.56	430.28	338.73	476.36	77.11	3.14	
9	331.74	400.02	400.56	430.28	338.77	477.42	77.72	2.70	
10	335.38	400.02	400.56	430.28	338.73	478.15	78.20	2.24	
11	339.93	399.97	378.48	419.24	-616.25	2360.60	2181.36	1.56	On extreme X-exit

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.56

Critical Circle: Xc = -616.25[ft], Yc = 2360.60[ft], R = 2181.36[ft]. (Number of slices used = 54)

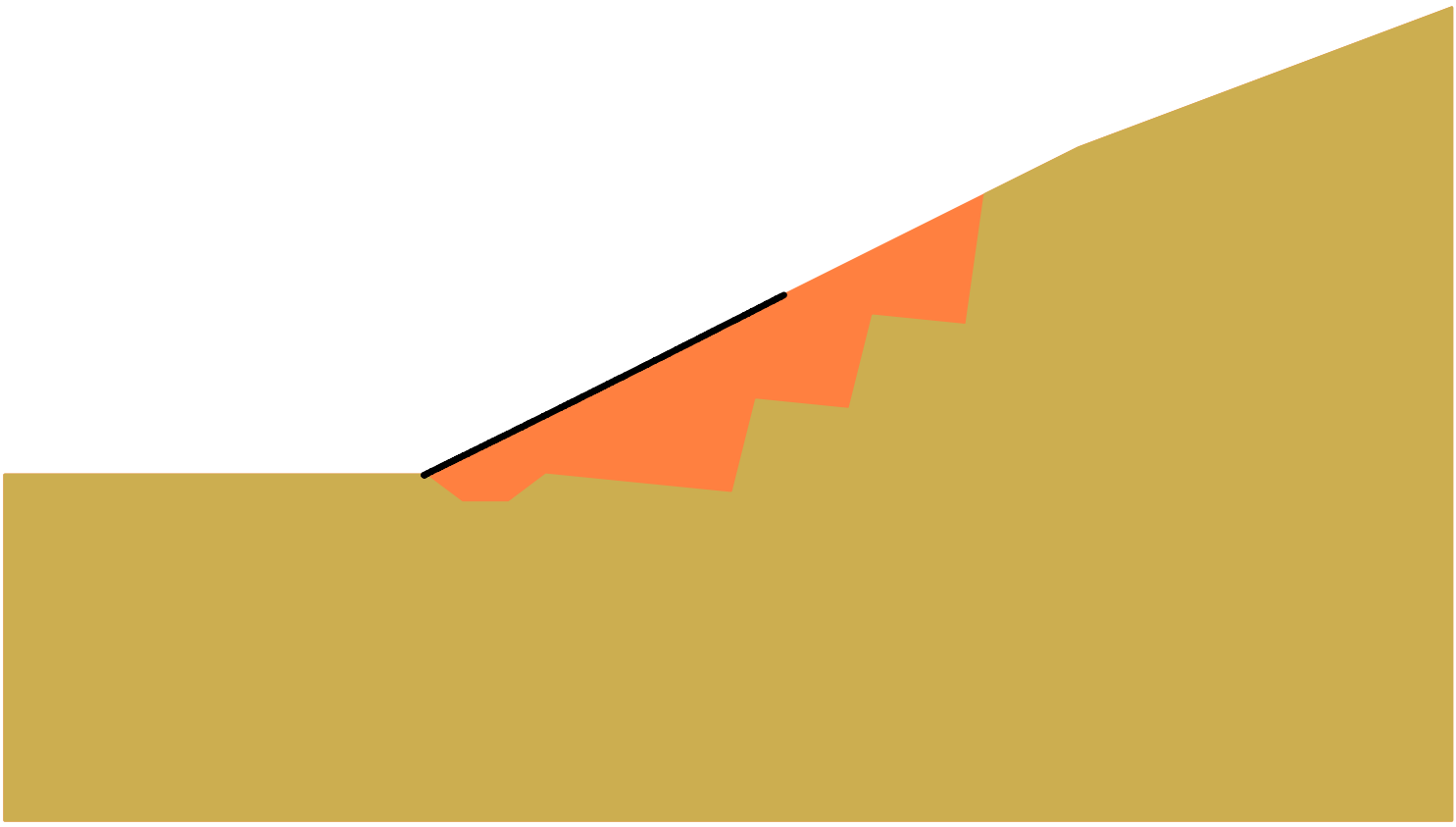
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

N O T C O N D U C T E D

Three-Part Wedge Stability Analysis

N O T C O N D U C T E D

REINFORCEMENT LAYOUT: DRAWING



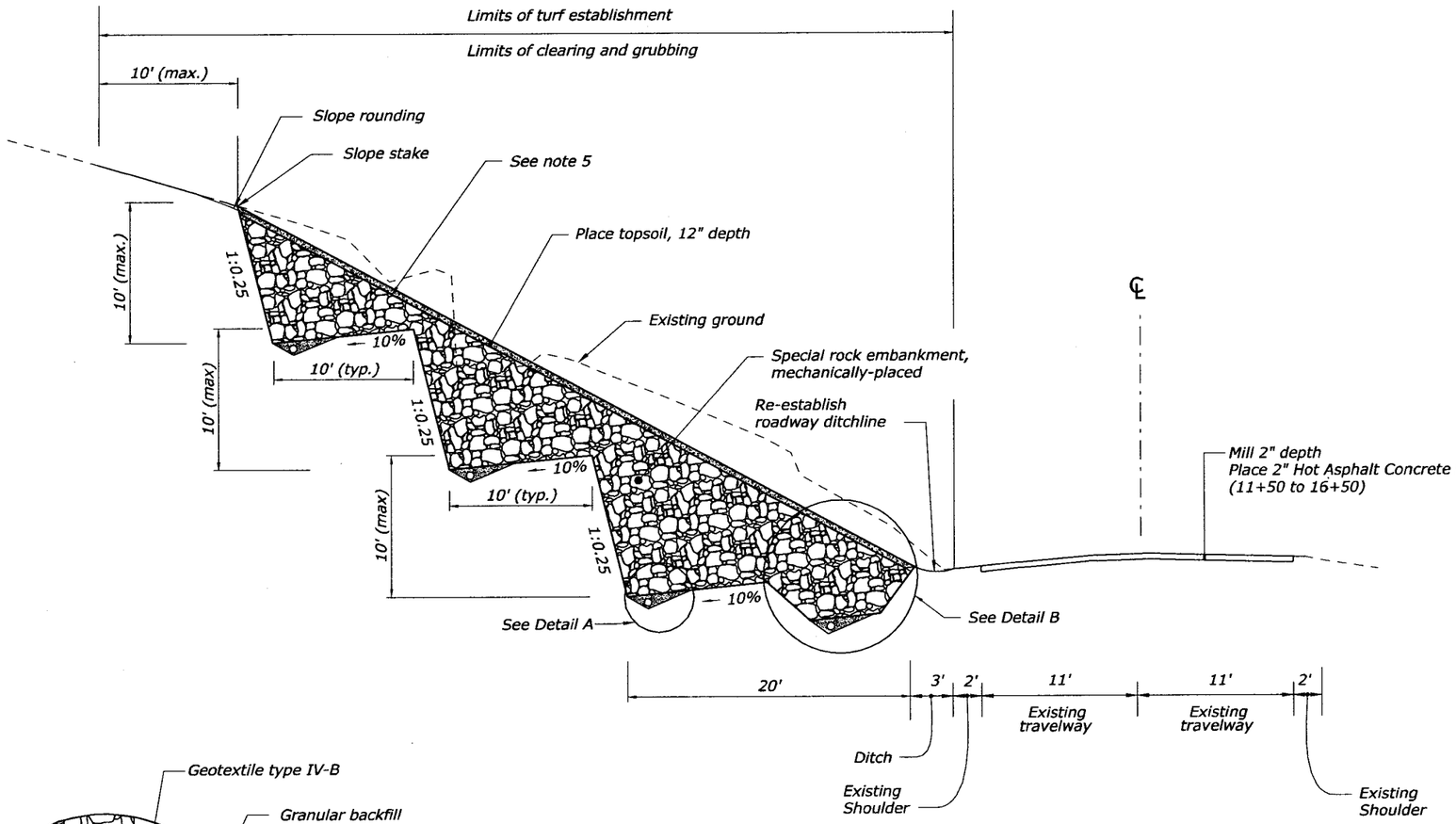
SCALE:

0 2 4 6[ft]

APPENDIX F

Typical Details

REG	STATE	PROJECT	SHEET NO.
SE	TN	PRA-FOOT 8G14	B1



Legend

Special rock embankment, mechanically placed

Granular backfill

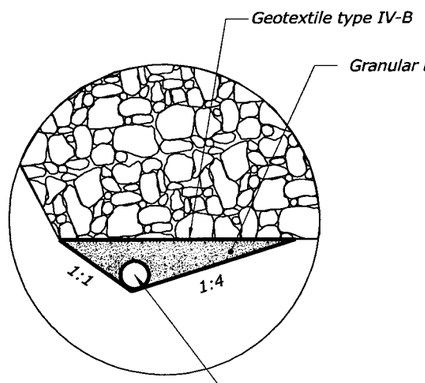
Notes:

1. Place topsoil and turf establishment on all disturbed areas in accordance with Sections 624 and 625.
2. Extend limits of repair to a minimum of 5 ft beyond the existing slide limits (10 ft max.).
3. Bench repair as follows:

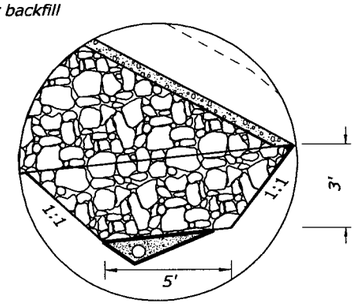
   (1) Provide a minimum 20 ft wide horizontal bench into the existing slope along the base of the repair area; thereafter,

   (2) Provide benches that are a minimum 10 ft wide horizontally and are a maximum 10 ft high vertically,

   (3) Provide benches with a 10(H):1(V) negative crossslope (10%).
4. Construct underdrain using perforated plastic pipe to provide positive drainage (min. 2% grade). Obtain approval by the CO of the final pipe location and outlet.
5. Use spalls smaller than the minimum rock size to chock the larger rock solidly into position, fill the voids between the larger rock and to provide a stable, dense surface for the placement of topsoil.
6. Shape surface of slide repair to match existing adjacent slopes as much as possible.



Detail A



Detail B

Typical Section
12+30 to 14+10

Not to scale

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION
STERLING, VIRGINIA

GREAT SMOKY MOUNTAINS NATIONAL PARK

FOOTHILLS PARKWAY

TYPICAL SECTIONS

3/28/2008 1:09:16 PM M:\Projects\roads\8g14\proj_dev\CADD\95% plans\50i-FOOT8G14i_typ.dgn

APPENDIX G

Representative Photographs

<u>Photo No. 1</u> – Looking southeast from NB lane

<u>Photo No. 2</u> – Looking south

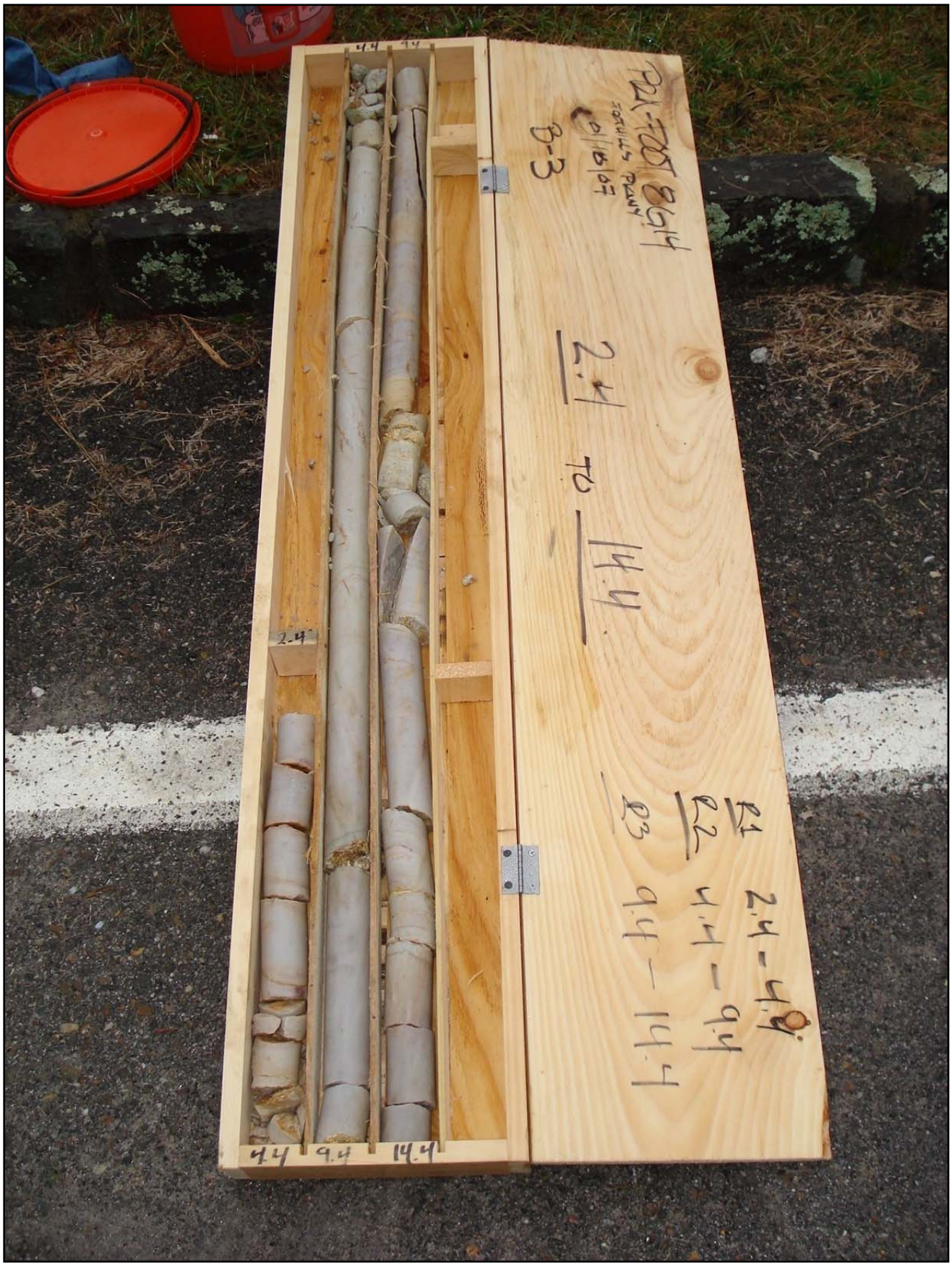
<u>Photo No. 3</u> – Looking southwest from SB lane

<u>Photo No. 4 – Looking east</u>

<u>Photo No. 5</u> – Looking west along top of slide

<u>Photo No. 5</u> – Looking west along top of slide

Photo No. 6 – Boring B-2 Rock Core



<u>Photo No. 7</u> – Boring B-3 Rock Core